



**CAPACITOR BANKS FOR BOOSTER RESONANT
POWER SUPPLY**

Jan Ryk

April 14, 1970

Preliminary studies regarding the capacitor banks for the Booster Resonant Power Supply were started in 1968. The goals set for the capacitors were the following.

1. Low losses
2. Low stray capacitance to ground
3. Low variation of capacitance as a function of temperature
4. High degree of reliability
5. Easy replacement of faulted units
6. Possibility of mounting the capacitors in the magnet support girder
7. Low cost

The following information was obtained from different capacitor manufacturers.

1. McGraw Edison Company
(Line material industries)
 - a. The typical variation of capacitance as a function of temperature between 20° and 50° C is 2½%, see Figure 1.

- b. Capacitor cans will usually not rupture if the energy dumped into a faulted can does not exceed 5 kJ.
- c. The typical capacitance from the terminals of a capacitor to the can is 2000 pico farads. This stray capacitance is constant to within 10% for a given design.

2. Sangamo Electric

- a. Typical variation of capacitance as a function of temperature over the temperature range of 20° to 50° C is $2\frac{1}{2}\%$, see Figure 2.
- b. Dissipation factor expected for 15 Hz operation is .6%, see Figure 3.
- c. Sangamo suggests to restrict the energy in a capacitor bank to 15 kJ based on consideration of rupture strength of standard fuses and capacitor cans.
- d. Oil impregnated multilayer kraft paper is usually used for dielectric. The winding of individual capacitor packs is done in a temperature, humidity, and dust controlled environment.

3. Maxwell Laboratories

- a. Typical dissipation factor expected at 15 Hz operation is .25%, see Figure 4.
- b. Typical dissipation factor dependence on temperature is shown in Figure 5.
- c. Typical impregnants used are:
 - . Aroclor, $k = 6$
 - . Silicone oil, $k = 4$, $\Delta C/\Delta T < -1\%$ over $20^{\circ} - 50^{\circ} \text{ C}$, practically doubles the cost of the capacitors
 - . Silicat ester, $k = 4$, similar to silicone oil, both silicone oil and silicat ester requires 50% more volume for the same capacitance, due to the low k .
 - . Mylar, $\Delta C = +20\%$ over 20° to 50° C ,
cost: 2 times that of aroclor capacitors;
losses: 2 times those for aroclor capacitors.
- d. Water-cooled capacitors: volume 20% higher than air-cooled capacitor due to cooling coil, cost is 35% higher, cooling efficiency 30 to 40%.
- e. Paper-film capacitors, using kraft paper and polypropylene film. Losses about 25% of those of paper capacitors, cost is twice as high, volume about 30% larger.

- f. Film capacitors: losses about 10% lower than for the paper dielectric, volume about 6 times larger, cost about 4 times higher.

Prototype Work

Based on the information received from the different manufacturers and guided by the goals set for the capacitor bank, we came to the following requirements for the Booster capacitor banks.

1. The dissipation factor at the expected operating temperature of 50° C should not exceed .3%.
2. In order to further limit the losses, no internal discharge resistors should be used.
3. The stray capacitance to ground should be minimized by mounting the capacitor units in an insulated structure, using single bushing capacitors. The total capacitance appears now between the single bushing and the can. With the can connected to the structure, the stray capacitance to ground is now determined by the insulation distance to ground which can be large.
4. Use paper impregnated with aroclor as the dielectric.

This is the lowest cost and the most compact unit. Aroclor is nonflammable and, therefore, good for indoor use. A test report prepared by Underwriters Laboratory regarding monsanto aroclor 1248 and 1242 is attached.

5. Can rupture is unlikely to occur since the maximum stored energy in a Booster capacitor bank is 6 kJ. In spite of this, the individual capacitor cans will be fused to definitely prevent can rupture. Fuses will be indicating type. Prevention of can rupture will prevent burning of the paper dielectric which can cause toxic fumes, as indicated in the report mentioned under Item 4. Capacitor can rupture curves and fuse clearing curves are attached (see Figures 6 & 7).
6. The capacitors will be assembled in modular structures designed to fit in the magnet support structure. Individual capacitor mounting and capacitor module mounting will be such that individual units or modules may be removed easily and fuse replacement can be achieved easily.
7. Air-cooled capacitors will be used, because of the following advantages over water-cooled units.

- a. Smaller volume
- b. Lower cost
- c. Elimination of extra cooling equipment

Furthermore, the maximum dissipation for air-cooled capacitors is 1040 watts over a total area of 3700 square inches or .28 watts/sq in. The water-cooled units could not be fitted in the available space in the magnet support girder.

In order to evaluate manufacturing capabilities and designs, we decided to obtain a prototype capacitor bank based on our specifications from three different manufacturers. The three different designs were evaluated by means of tests at the manufacturers' plants and tests at NAL.

Final Capacitor Banks

The final capacitor banks decided upon have the following design parameters.

Total capacitance per bank	8300 μ F \pm 30 μ F
Number of modules	3
Number of capacitor units per bank	17 + 1 trimmer
Operating voltage	815 V rms
Operating frequency	15 Hz

Dielectric

Voltage stress	450 Volts/mil
Material	Kraft Paper
Paper density	.9
Impregnant	Monsanto aroclor 1242
Number of layers	4
Thickness per layer	.00045 inch
Total paper thickness	.0018 inch
Foil	Aluminum
Construction	Tabbed
Number of tabs/foil	2
Number of sections/can	12
Can dimensions	26" x 13½" x 6"
Capacitance per can	490 ± 10 µF
Dissipation factor	.2%
Losses per bank at 815 Vrms	1040 watts
ΔC over 50° F to 120° F	2.37%
Can temperature rise at 1120 V peak	15° C
Spacing between cans	1½"
Life expectancy	20 years
Fuse rating	1200 V-75A
Fuse type	Westinghouse CLC

Trimmer Unit

4 bushings, respectively, at 1/8, 1/8, 1/4, and 1/2 of the capacitance value of a standard can, construction identical, number of sections: 16.

Tests

The following factory tests were performed to assure that the capacitor banks met the NAL requirements.

1. The dissipation factor was measured at:

60 Hz, 815 Vrms, 80° C ± 5° C (all units)
120 Hz, low voltage, room temperature (all units)
60 Hz, 600 Volts, room temperature (10% selection)
60 Hz, 600 Volts, 120° C ± 1° C (10% selection)

2. The capacitance was measured at:

120 Hz, low voltage, room temperature (all units)
60 Hz, 600 Volts, room temperature (10% selection)
60 Hz, 600 Volts, 85° C ± 5° C (10% selection)
60 Hz, 600 Volts, 120° C ± 1° C (10% selection)

3. All units were subjected to a switching surge test consisting of:

Full rated voltage, 60 Hz, for two seconds
Zero voltage for one second
Full rated voltage, 60 Hz, for two seconds
Zero voltage for one second
Two times rated voltage, 60 Hz, for ten seconds.

The capacitance and dissipation factor were measured with a low voltage, 120 Hz bridge before and after the switching surge test.

4. One unit, after it had passed all of the above tests, was charged up by means of a dc power supply until destruction. The unit failed at 7 kV, which corresponds with a stored energy of $1/2 \times 490 \times 10^{-6} \times (7000)^2 = 12,000$ Joules. The can bulged but did not rupture.
5. A small quantity of the aroclor impregnated paper dielectric in open air was burned by means of an open flame. The paper burns readily, the aroclor caused black smoke with irritating fumes. (Also see the Underwriters' Laboratories test report on aroclor.)

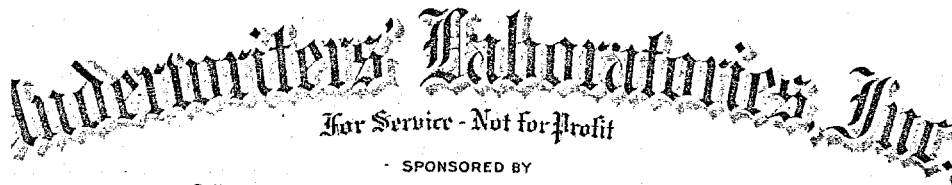
In addition to the factory tests, one complete capacitor bank was operated at NAL under normal 10 GeV operating conditions. The capacitor bank was mounted in a typical magnet support structure, placed in the Booster Prototype tunnel. The can temperatures were recorded under these conditions. The maximum can temperature rise was 15° C. The time necessary to reach a stable temperature was $4\frac{1}{2}$ hours.

Conclusions

Typical performance curves of the capacitors are shown in Figures 8 through 12. All units were fabricated from one shipment of paper. The temperature and humidity during winding of the capacitors was controlled. The result was small capacitance tolerance between individual cans.

The units that passed the stringent factory tests may be considered very reliable. If we assume that one unit is representative, we may conclude from factory test No. 4 that can rupture under fault condition in the Booster system is very unlikely since the maximum energy in a capacitor bank at 10 GeV operation is 6 kJ and the test can did not rupture under failure at 12 kJ.

Under these conditions we do not expect the capacitors to form a fire hazard. The aroclor impregnant is non-flammable at normal temperatures. As long as no can rupture occurs, the paper will not burn.



National Board of Fire Underwriters

207 EAST OHIO STREET, CHICAGO 11

Miscellaneous Hazard 2581
Application No. 49C2096

November 8, 1949

REPORT

on

LIQUID DIELECTRIC AND COOLING MEDIUMS

General Electric Co.,
Schenectady, N.Y.

I N T R O D U C T I O N

Since issuance of our listings of Pyranols covered in our reports of September 29, 1934, April 14, 1936, April 9, 1940, August 7, 1941, December 1, 1942, and March 16, 1944, this manufacturer has developed additional liquid dielectric and cooling mediums designated as "Pyranol Nos. 1498 and 1499".

D E S C R I P T I O N

PRODUCTS COVERED BY THIS REPORT:

Liquid dielectric and cooling mediums,
"Pyranol Nos. 1498 and 1499."

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GENERAL CHARACTER AND USE:

The products which are the subject of this report are chlorinated aromatic hydrocarbons. They are intended for use as dielectric and cooling mediums in electrical apparatus. They are not intended to replace oil as a dielectric and cooling medium unless equipment is designed for either oil or these products.

MARKING:

"Pyranol Nos. 1498 and 1499."

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T H E I N V E S T I G A T I O N

The object of this investigation was to determine the fire and explosion hazard of the products.

In planning the investigation consideration was given to the General Nature of the products, their Fire and Toxic Hazard, Corrosive Action, Stability, and Uniformity. The method of investigation of each of these phases is given below.

Information as to the general nature of the products was obtained by means of Identification Tests.

In the study of fire and toxic hazards, the product was investigated as to flammability, explosiveness of the vapors when mixed with air, products of decomposition, and decomposition temperature. The tests included Flash Point Tests, Fire Tests, Ignition Temperature Tests, Tests for Explosiveness of Vapors in Air, Explosive Range Tests, Decomposition Temperature Tests, and Analytical Tests of Decomposition Products.

Corrosion Tests on metals commonly used in electrical apparatus were conducted. In view of the similarity of the products, corrosion tests were conducted on only one of the two products submitted.

Information bearing on the stability of the products was obtained from Decomposition Temperature Tests, Corrosion Tests, and consideration of the chemical properties of the products.

The process for manufacturing the products is subject to definite control, and a detailed investigation of factory process was not therefore considered necessary.

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E X A M I N A T I O N A N D T E S T R E C O R D

DESCRIPTION OF SAMPLES

The manufacturer furnished 5-gal samples of the products, Pyranol Nos. 1498 and 1499.

IDENTIFICATION TESTS:

METHODS

Specific Gravity - The specific gravity was determined by means of a pycnometer.

Test for Chlorine - A few drops of the product together with a small piece of metallic sodium are heated in a test tube over a bunsen burner. After the reaction is completed, the test tube is broken in water; the resulting solution is filtered; and nitric acid and silver nitrate solution are added. The formation of a white precipitate indicates the presence of chemically combined chlorine.

Distillation Test - A 100-g sample was distilled using the method (D20-30) of the American Society for Testing Materials.

RESULTS

The results of the identification tests are recorded in Table I.

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TABLE I
RESULTS OF IDENTIFICATION TESTS

	Pyranol No. 1498	Pyranol No. 1499
Specific Gravity at 15.6 C (60 F) 15.6 C (60 F)	1.456	1.384
Chlorine	Present	Present
Distillation Test: Initial Boiling Point	330.0 C (626 F)	312.0 C (594 F)
Temperature	Amount distilled	Amount distilled
Below 335 C (635 F)	-	88.7% by weight
Below 340 C (644 F)	60.5% by weight	-
340 C (644 F) to 350 C (662 F)	27.5% by weight	-
350 C (662 F) to 379 C (714 F)	9.5% by weight	-
335 C (635 F) to 358 C (676 F)	-	10.2% by weight
End Point	379 C (714 F)	358 C (676 F)
Residue	1.3% by weight	0.8% by weight
Distillation Loss	1.2% by weight	0.3% by weight

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FLASH POINT TESTS:

METHOD

The flash point was determined with the Pensky-Martens closed tester using the method (D93-46) of the American Society for Testing Materials.

RESULTS

The results of the flash point tests are as follows:

<u>Sample No.</u>	<u>Flash Point</u>	(2)
1498	196.1 C (385 F)	
1499	176.7 C (350 F)	

FIRE TESTS:

METHODS

The fire tests were made with the Cleveland open cup, using the method (D92-46) of the American Society for Testing Materials.

RESULTS

The sample Nos. 1498 and 1499 gave negative results in the fire tests. (4)

(3)

-
- (2) In this connection, see Note 4.
 - (3) Intermittent flashes were obtained but the product did not continue to burn. The sample was heated to boiling point; the test was then discontinued.
 - (4) In view of the negative results obtained in the Fire Tests, it is clear that the flash point test cannot be depended upon to give a true measure of the fire hazard of these products. It was therefore necessary to conduct Tests for Explosiveness of Vapors in Air. See Page 9.

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IGNITION TEMPERATURE TESTS:

METHOD

The apparatus consists essentially of a combustion chamber surrounded by a solder bath, which is heated at a constant temperature during the test by a bunsen burner. The temperature of the solder bath is measured by means of a calibrated thermocouple provided with a quartz tube to protect the hot junction.

The combustion chamber consists of a quartz flask of conical form with flat bottom, 4-1/2 in. (11.4 cm) in height, 2-3/8 in. (6.0 cm) in diameter at bottom, and 1-1/8 in. (2.8 cm) in diameter at top. It is of about 160-cc capacity (rated capacity 125 cc) having a ratio of surface area to volume of about 1.1.

Measured test samples in the liquid phase are introduced into the heated combustion chamber by means of a micro pipette. Different amounts of the sample are admitted to the chamber in successive tests in order to determine the minimum temperature at which the vapor of the liquid in any proportion with air will ignite. The residual vapors or gases in the combustion chamber are completely displaced by a stream of air in the interval between tests,

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RESULTS

The results of the ignition temperature tests are tabulated below:

<u>Sample No.</u>	<u>Ignition Temperature</u> (5)
1498	672 C (1243 F)
1499	652 C (1206 F)

-
- (5) The main value of the ignition test is to determine the minimum temperature required to produce ignition under the most favorable conditions in the absence of a flame or spark including ratio of vapor to air and ratio of heated surface to volume of vapor-air mixture. Under less favorable conditions as when the liquid is applied to a hot plate a higher temperature for ignition is required. A limitation of the ignition test in a small vessel is that it does not show whether flame propagation for any material distance will occur. After determining the ignition temperature therefore it is necessary to obtain additional data having a bearing on flame propagation. These data are given by Tests for Explosiveness of Vapors in Air.

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TESTS FOR EXPLOSIVENESS OF VAPORS IN AIR:

METHOD

The apparatus consists of a cylindrical steel vessel 6 in. in diameter (internal) and 26 in. long. It is provided with a small mica window and an outlet to the atmosphere. The apparatus is heated externally by gas burners. Openings are provided half way between the ends of the vessel to admit electrode terminals connected to an induction coil. The electrode terminals are spaced to give a spark gap of 1/4 in.

An iron-constantan thermocouple connected to a potentiometer is used for rough measurements of the temperature of the vapor inside of the vessel.

Samples ranging in volume from 20 to 80 cc were introduced into the cylinder which had previously been heated to a predetermined temperature. The outlet of the cylinder was closed with a loose asbestos plug. Sparks were passed between the electrode terminals at intervals of one-half minute.

Residual gases and vapors were displaced from the cylinder by a stream of air in the interval between tests.

RESULTS

Sample No. 1498 - No propagation of flame occurred at temperatures up to 148 C (298.4 F). Flame propagation with weak pressure effects (sufficient to push asbestos plug from outlet of cylinder) occurred at 150 C (302 F). Moderate pressure effects (asbestos plug thrown about 3 or 4 ft horizontally from outlet of cylinder) were obtained at temperatures somewhat above 150 C (302 F).

Sample No. 1499 - No propagation of flame occurred at temperatures up to 141 C (285.8 F). Flame propagation with weak pressure effects (sufficient to push asbestos plug from the outlet of cylinder) occurred at 144 C (291.2 F). Moderate pressure effects (asbestos plug thrown about 3 or 4 ft horizontally from outlet of cylinder) were obtained at temperatures somewhat above 144 C (291.2 F).

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EXPLOSIVE RANGE TESTS:

METHOD

The apparatus consists essentially of a glass chamber equipped with a spark gap and a stirrer. The chamber is cylindrical with the lower end hemispherical and is approximately 3 in. in diameter by 8 in. in height; it has a net volume of 863 cc. The apparatus is provided with a glass lid supporting the stirrer and the leads to the spark gap near the bottom of the chamber. An opening in the lid is provided for introduction of the sample. The glass chamber is immersed in a molten solder bath to a depth of 6 in.

In conducting tests the solder bath was maintained at a constant temperature of 400 C (752 F), a measured quantity of the liquid to be tested was placed in the apparatus, and the vapors stirred. Sparks were then passed at the spark gap while observations were made for flame travel and pressure effects. Following the test the vapors were displaced by a slow stream of compressed air in preparation for the next test.

RESULTS

The results of the explosive range tests of Samples Nos. 1498 and 1499 in air at 400 C (752 F) are shown in Table II.

DECOMPOSITION TEMPERATURE TESTS:

METHOD

The apparatus described in connection with Ignition Temperature Tests was used in these tests. The vapors evolved on introducing samples into the heated chamber were tested with moist blue litmus paper, a change in the color of the paper from blue to red indicating decomposition of the product. The minimum temperature at which litmus paper showed an appreciable change in color within a short time (3 min) was considered to be the decomposition temperature.

RESULTS

The results of the decomposition temperature tests are recorded in the following table.

<u>Sample No.</u>	<u>Decomposition Temperature</u>
1498	305 C (581 F)
1499	309 C (588 F)

TABLE II
RESULTS OF EXPLOSIVE RANGE TESTS

Sample No.	Lower Limit			Upper Limit		
	Volume Used in Test CC	Lb Vaporized Liquid per 1000 Cu Ft of Air (Calculated)	Per Cent by Volume (Calculated)	Volume Used in Test CC	Lb Vaporized Liquid per 1000 Cu Ft of Air (Calculated)	Per Cent by Volume (Calculated)
1498	0.033	3.5	1.1	0.119	13.0	3.9
1499	0.038	3.9	1.3	0.110	11.4	3.9

Weak pressure effects were obtained in these tests, as could be expected for mixtures near the limits of flammability.

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ANALYTICAL TESTS OF DECOMPOSITION PRODUCTS:

METHOD

The cylinder previously described under Tests for Explosiveness of Vapors in Air was also used for exposing vapor-air mixtures to hot iron surfaces. Connections for withdrawing samples of the decomposition products for analysis were inserted in the outlet pipe. The cylinder was externally heated to a temperature of 600 C (1112 F) by gas burners.

Samples of the product in the liquid phase were introduced into the heated cylinder at a uniform rate. Samples of the decomposition products were withdrawn from the outlet pipe and hydrochloric acid, free chlorine, phosgene, carbon dioxide, oxygen, carbon monoxide, gases absorbed by fuming sulphuric acid and methane and other paraffin hydrocarbon gases, were determined using the following methods.

Tests for free chlorine were made by liberation of iodine from aqueous potassium iodide solution and subsequent titration with sodium thiosulphate solution using starch solution as an indicator. A measured sample was drawn by a calibrated aspirator bottle through a train consisting of two spiral form bubbling towers containing potassium iodide solution.

Phosgene was determined by absorption in aqueous aniline solution. Phosgene reacts quantitatively with aniline to form diphenylurea, one molecule of phosgene being equivalent to one molecule of diphenylurea.

A measured sample was drawn through a train of three bubbling towers containing freshly prepared aqueous aniline solution saturated with diphenylurea. Free chlorine interferes with the determination and was removed by granulated antimony contained in a tube through which the sample passed before it entered the bubbling towers. The precipitate of diphenylurea was separated from the aniline solution by filtration, washed with cold water, dissolved in ethyl alcohol, recrystallized, dried, and weighed.

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Samples of the decomposition products were also collected in evacuated glass sampling tubes. In these samples hydrochloric acid was determined by solution in water and titration with standard alkali solution; carbon dioxide, carbon monoxide, oxygen, gases absorbed by fuming sulphuric acid, hydrogen, and paraffin hydrocarbon gases, were determined with the Burrell form of gas analysis apparatus after treating the sample with silver nitrate solution to remove hydrochloric acid.

RESULTS

The results of analytical tests of the decomposition products in the presence of hot iron surfaces are shown in Table III.

CORROSION TESTS:

METHOD

The metals used in the corrosion tests were copper, yellow brass, iron, tin-lead solder, and copper and iron coupled. Test specimens, 3/4 in. wide and 6 in. long were cut from sheets of the metals. The specimens were buffed, measured, cleansed with soap and water, washed with ethyl alcohol and ethyl ether, dried, and weighed.

Each specimen was immersed for half its length in a sample of the product contained in a glass tube provided with a cork stopper. The tubes were heated to a temperature of 90 C in an electrically-heated oven controlled by a thermostat.

The samples were examined visually at weekly intervals during the test for evidences of corrosion. At the conclusion of the test, the specimens were cleansed, dried, weighed and the change in weight per square centimeter of surface area calculated.

RESULTS

When heated in glass tubes containing Sample No. 1498 at 90 C for 1465 hours, the specimens showed little visible evidence of corrosion except for a slight discoloration of the surfaces above the liquid. The change in weight of the specimens was very small (less than 1.0 mg per sq cm).

TABLE III
RESULTS OF ANALYTICAL TESTS OF DECOMPOSITION PRODUCTS IN
PRESENCE OF HOT IRON SURFACES

					Sample No. 1498		Sample No. 1499	
					5 Min After Start of Test	13 Min After Start of Test	5 Min After Start of Test	13 Min After Start of Test
Hydrochloric Acid	Per Cent by Volume				22.3	44.8	25.3	34.8
Carbon Dioxide	"	"	"	"	16.9	10.5	20.8	24.1
Carbon Monoxide	"	"	"	"	12.2	13.0	8.7	11.8
Oxygen	"	"	"	"	2.7	4.4	6.2	0.6
Gases Absorbed by Fuming Sulphuric Acid	"	"	"	"	0.5	0.4	0.5	0.7
Hydrocarbon gases cal- culated as methane	"	"	"	"	1.4	1.4	2.5	1.6
Hydrogen	"	"	"	"	0.7	3.5	0.8	3.8
					5 to 13 Min After Start of Test		5 to 13 Min After Start of Test	
Chlorine	Per Cent by Volume				0.000		0.000	
Phosgene	"	"	"	"	0.000		0.000	

In addition to the above volatile decomposition products some finely divided carbon was formed.

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R E C O R D I N S E R V I C E

The type of material represented by Pyranols Nos. 1498 and 1499 has been in commercial service in increasing amounts during the past several years. The value of these liquids as dielectric and cooling mediums has been demonstrated.

T H E S U B M I T T O R

The manufacturer, the General Electric Company, Schenectady, New York, is experienced in the manufacture of electrical apparatus and related products, many of their products being listed by Underwriters' Laboratories, Inc.

SUPERVISION OF PRODUCTS BY UNDERWRITERS' LABORATORIES, INC.

The products will be placed under Reexamination Service.

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GENERAL NATURE:

These products are chlorinated aromatic hydrocarbons.

The results of the Identification Tests conducted indicate that the products are essentially hydrocarbons containing combined chlorine.

FIRE AND TOXIC HAZARD:

These products are nonflammable at ordinary temperatures. They are capable of forming moderately combustible and explosive mixtures with air under laboratory test conditions at higher temperatures, beginning at a temperature level of 150 C (302 F), in case of Pyranol No. 1498 and 144 C (291.2 F) in the case of Pyranol No. 1499, but under practical conditions formation of combustible or explosive mixtures is regarded as extremely unlikely. The fire hazard is very small.

It will be noted that the flash points of the products are comparatively high, and that a so-called "fire point" was not obtained. While intermittent flashes occurred in this test, the products did not continue to burn. The flash point and so-called "fire point" tests, particularly the latter, in the case of chlorinated hydrocarbons are of limited value as a measure of fire hazard but are useful for purposes of identification. The practical significance of the above tests in the case of the products in question is that their fire hazard is of a low order.

As shown by the results of Tests for Explosiveness of Vapors in Air, vapors of Pyranol No. 1498 failed to ignite or explode in tests at 148 C (298.4 F) but weak combustion occurred in tests at 150 C (302 F). Vapors of Pyranol

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No. 1499 failed to ignite or explode in tests at 141 C (285.8 F) but weak combustion occurred in tests at 144 C (291.2 F). Moderate explosions were obtained in tests at temperatures somewhat above these minimum values. At a temperature of 400 C (752 F) the lower limits of flammability (upward propagation) of the vapors of Pyranol Nos. 1498 and 1499 were found to be 1.1 per cent and 1.3 per cent by volume in air respectively and the corresponding upper limits of flammability (upward propagation) were found to be 3.9 per cent by volume. It will be noted that these are comparatively narrow explosive ranges.

The minimum ignition temperatures of the products were found to be 672 C (1243 F), and 652 C (1206 F) for Pyranol Nos. 1498 and 1499 respectively as recorded in the results of Ignition Temperature Tests.

The gases produced by burning or decomposition of the products by heat are nonflammable or nonexplosive alone or mixed with air. In previous tests of similar products the gases formed by burning or decomposition were similar irrespective of whether formed by hot surfaces or electric arcs.

The gases or fumes produced by decomposition of the products include hydrochloric acid and carbon monoxide. This will ordinarily constitute a toxic hazard only where the conditions are such as to cause confinement of the fumes as in a closed room in which combustion or decomposition of the products is maintained by fire, highly heated surfaces, or electric arcs.

It is to be noted in this connection that oils in common use at present as the dielectric medium for electrical apparatus are readily combustible and when burning under conditions of restricted air supply form carbon monoxide in dangerous concentrations.

The resulting concentration of hydrochloric acid in air when failure of a transformer or other electrical apparatus containing these products occurs will depend largely upon the conditions. It will constitute a toxic hazard only where the conditions are such as to cause a high concentration of the fumes as in a closed room. In ordinary use, the small quantities of gases evolved will be vented to some safe location.

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The exceedingly unpleasant and irritating fumes from the decomposition of these products even in concentrations of a very low order act not only to give warning of their presence but to prevent dangerous exposure of persons. While carbon monoxide is odorless and toxic its formation from these products is always accompanied by the simultaneous formation of hydrochloric acid gas which gives adequate warning of its presence as brought out above.

It will be noted that combustion and decomposition of the products was maintained by heated surfaces (600 C, 1112 F) in carrying out the analytical tests of the decomposition products. As shown by the results of the Decomposition Temperature Tests, the products were not appreciably decomposed at temperatures below 305 C (581 F).

CORROSIVE ACTION:

The products do not corrode the metals commonly used in electrical apparatus.

No corrosion occurred in the tests conducted on representative metals and alloys as recorded under Corrosion Tests.

It will be noted from the results of Analytical Tests of Decomposition Products that appreciable amounts of hydrogen chloride are formed on combustion or decomposition of the products in the presence of hot metal surfaces.

STABILITY:

The products are reasonably stable and in use are unlikely to undergo decomposition resulting in an increase in fire hazard.

In the Decomposition Temperature Tests the products did not undergo appreciable decomposition at temperatures below 305 C (581 F). Considerations of the chemical structure and properties of the products also indicate that they are reasonably stable.

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UNIFORMITY:

Considering the general process of manufacture,
it appears to be practicable to maintain a high standard
of uniformity on a commercial scale.

R E C O M M E N D A T I O N

TO THE ELECTRICAL AND FIRE COUNCILS OF UNDERWRITERS'
LABORATORIES, INC.

We recommend promulgation of the following notice
to subscribers and the action indicated thereby:

Guide No. 80 IO. November 8, 1949. File MH2581.

General Electric Co., Mfr.,
1 River Rd., Schenectady, N.Y.

Dielectric Mediums.

Synthetic liquids intended for use as dielectric and
cooling mediums in electrical apparatus, particularly
transformers, cables, and capacitors.
Nonflammable and nonexplosive at ordinary temperatures.
Marking: "Pyranol Nos. 1498 and 1499."

Listed by Report - Further information is contained in
a report dated November 8, 1949, copy of which may
be obtained either from the manufacturer or from
Underwriters' Laboratories, Inc. (These products
are not intended to replace oil as a dielectric
and cooling medium unless equipment is designed
for either oil or these products.)

See description of Reexamination Service on guide card.

Tests by:
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A. F. MATSON
Chemical Engineer

The foregoing Recommendation has been accepted
12-27-49
UNDERWRITERS' LABORATORIES, INC.,

(SIGNED) W. S. Austin
Secretary

CCC:LZ

CAPACITANCE CHARACTERISTICS OF HEMEX IMPREGNATED CAPACITORS AT VARIOUS TEMPERATURES

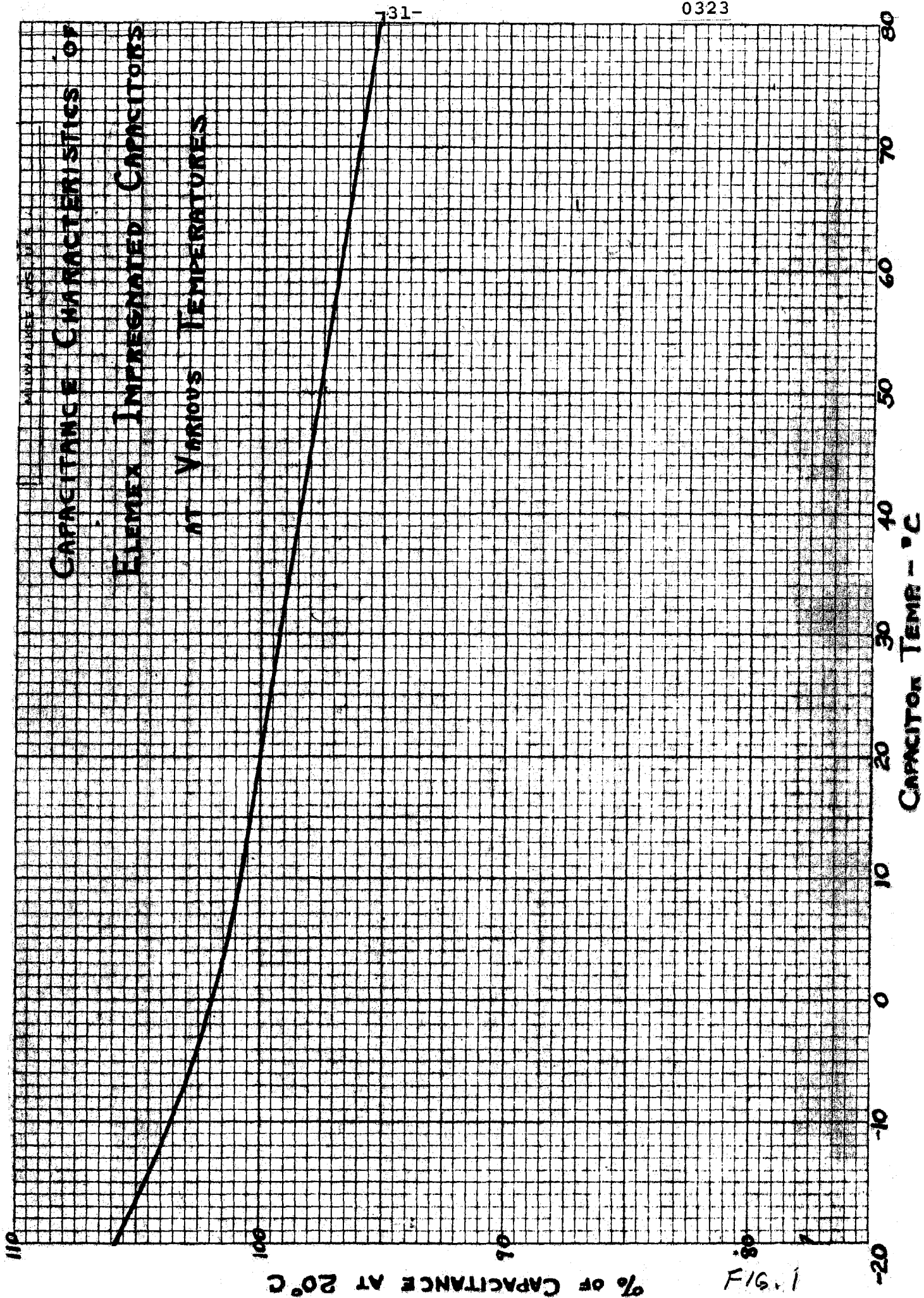
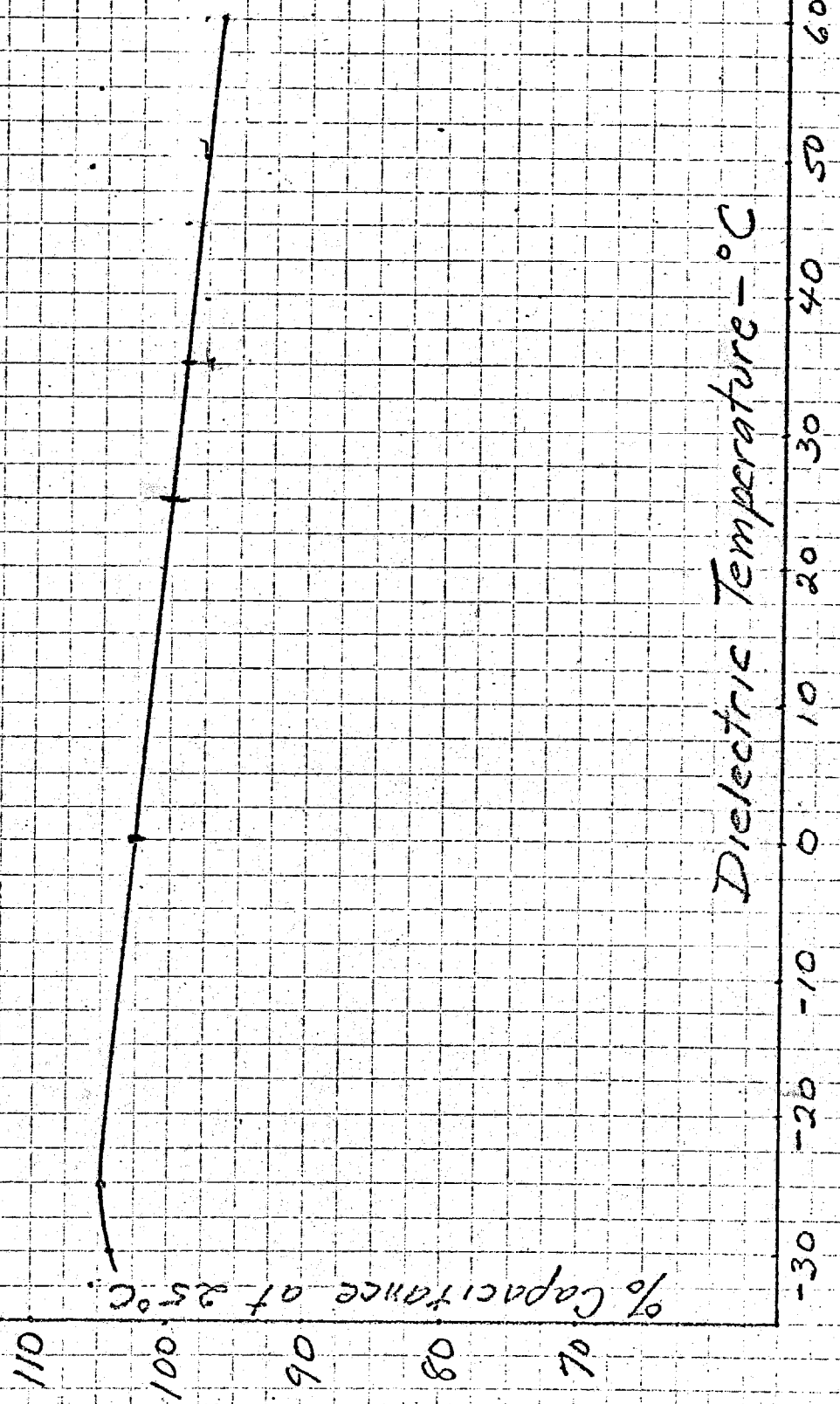


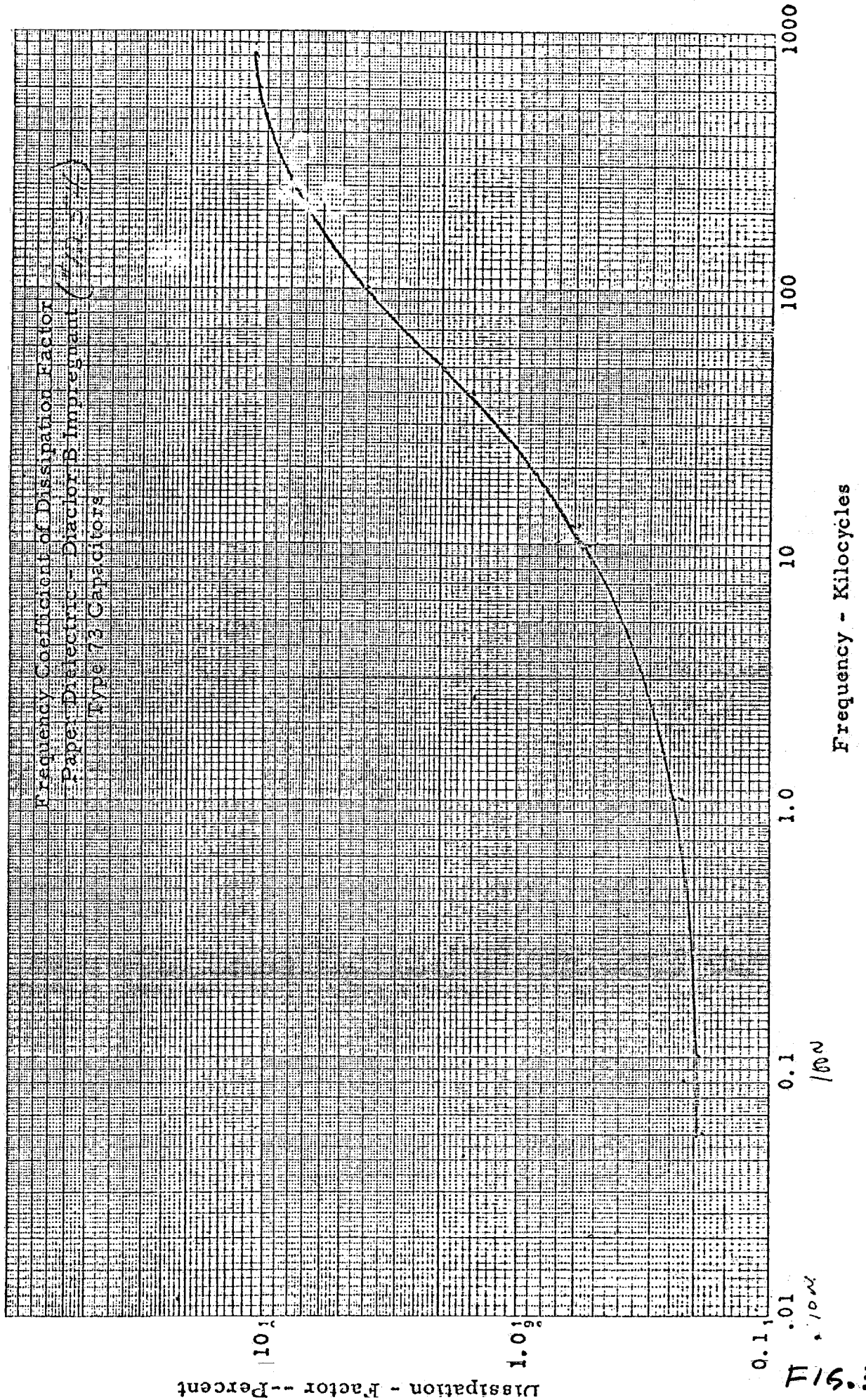
FIG. 1

Relative Capacitance in Percent
25°C - 60 Cycle of Value vs Dielectric
Temperature
100 KVAR Power Capacitor



Test #66121
JFK

FIG. 2



Dissipation - Factor -- Percent

Frequency - Kilocycles

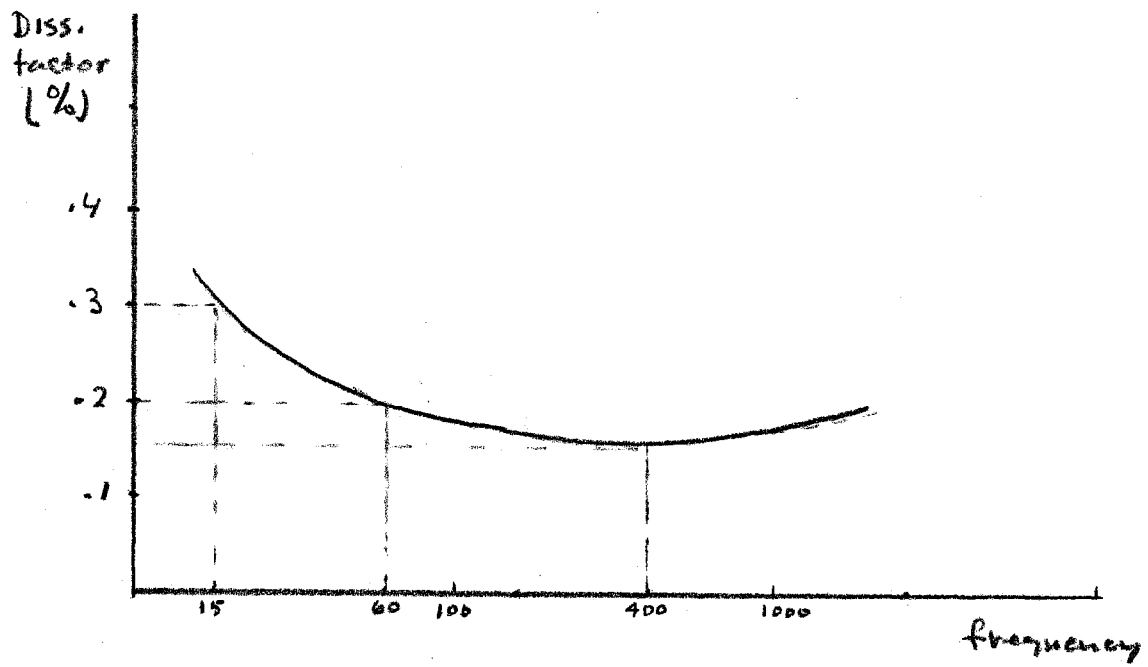


FIG. 4

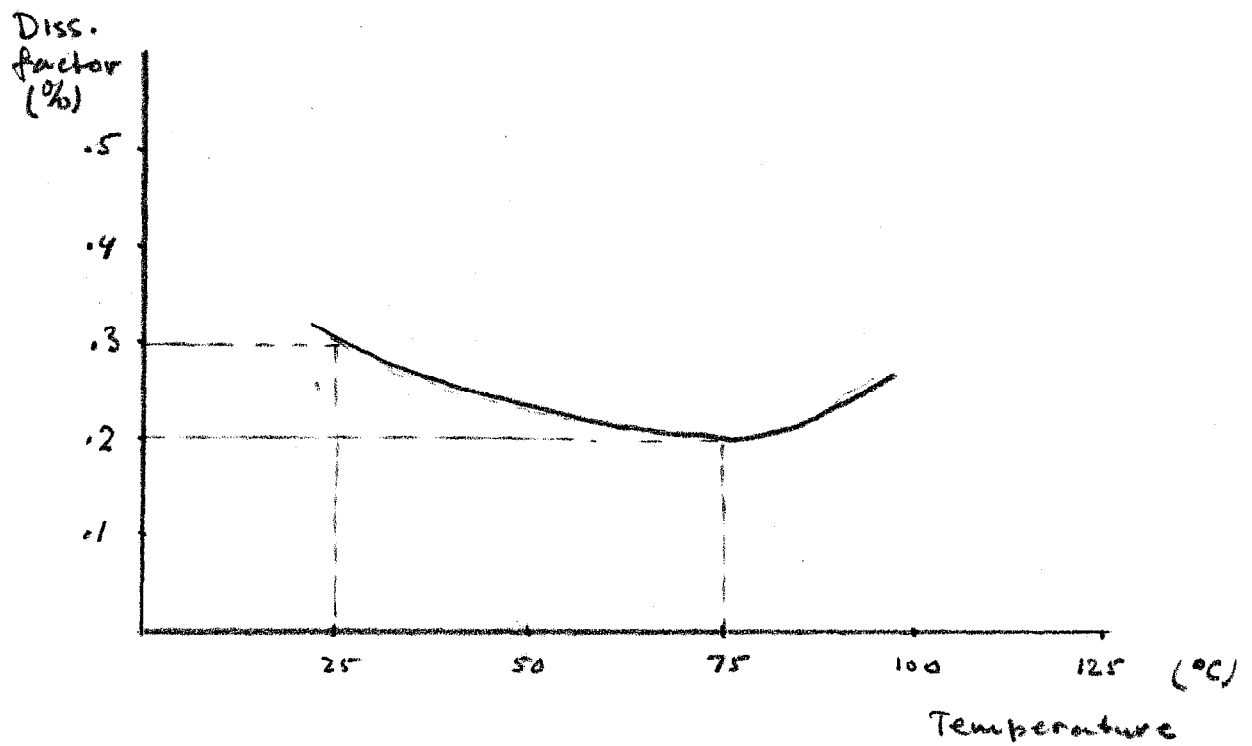
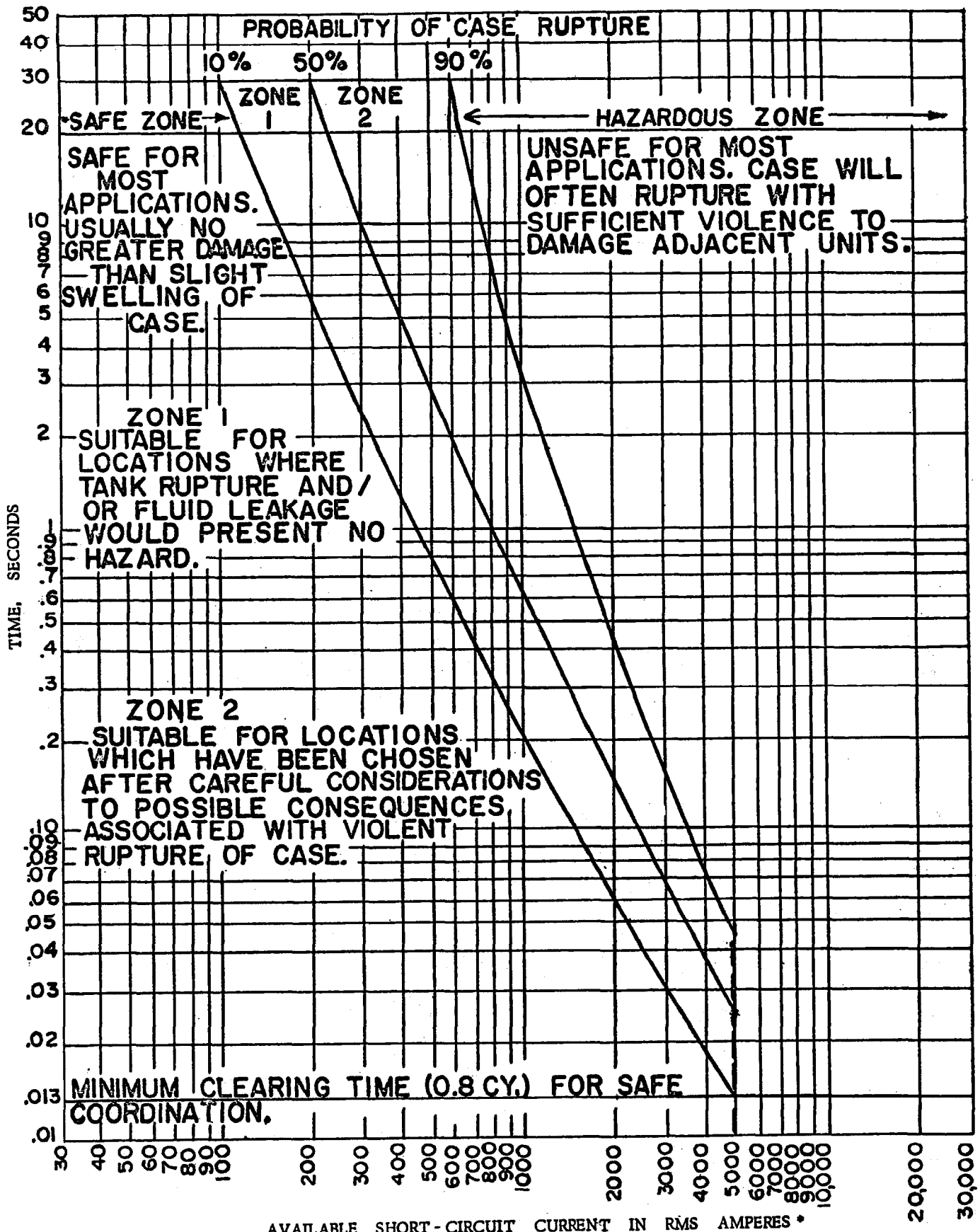


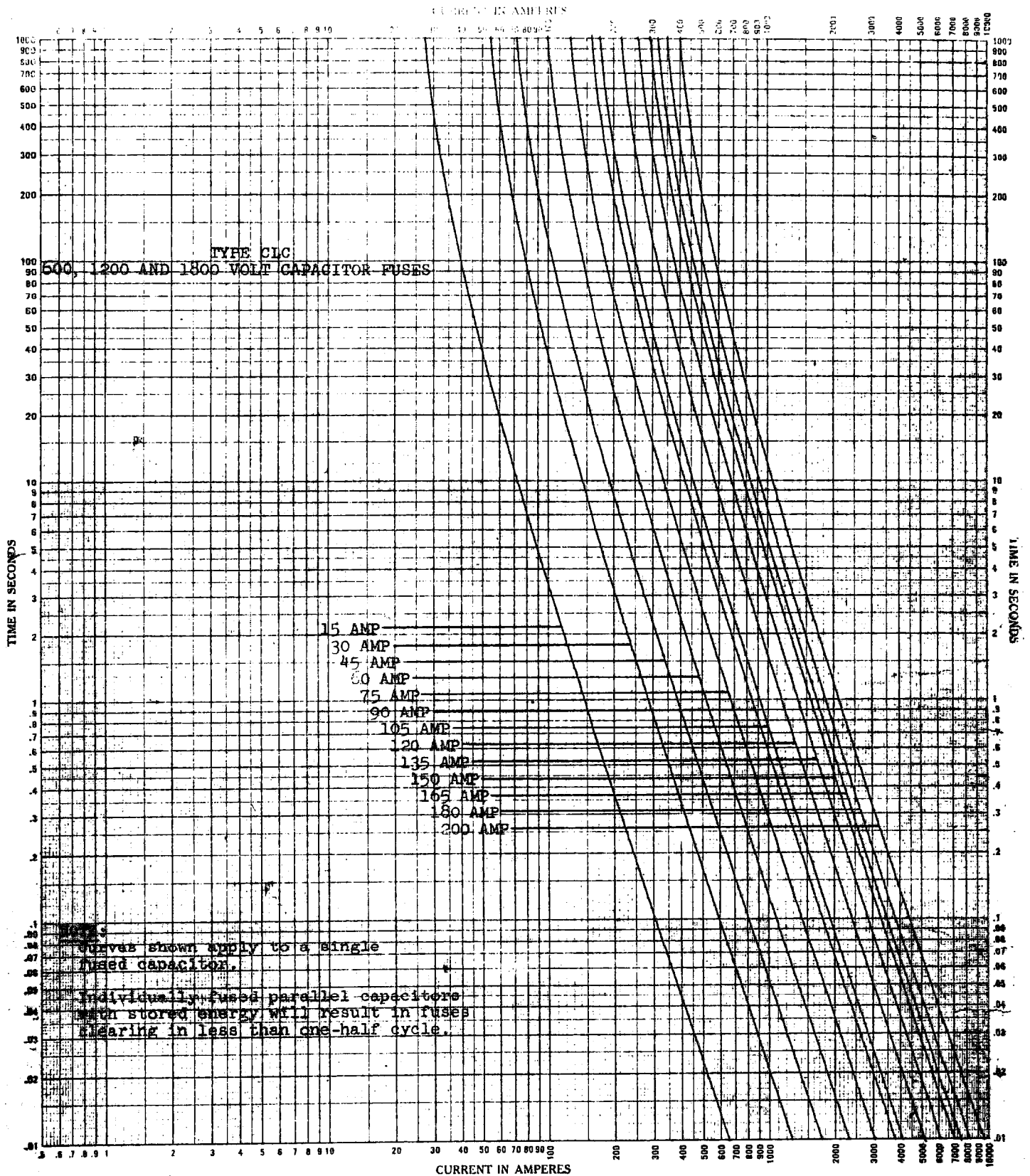
FIG. 5



*For times shorter than 1 cycle use asymmetrical rms amperes.

Fig. 6-3
CURRENT-VERSUS-TIME FOR A CAPACITOR UNIT TO RUPTURE DUE TO GAS PRESSURE
CAUSED BY INTERNAL ARCING FOR 100 KVAR UNITS

FIG. 6



Total Clearing		TIME-CURRENT CHARACTERISTIC CURVES	
For Type CLC Capacitor Fuses		Fixed In	
BASIS FOR DATA Standards		Dated	
1. Tests made at Rated Volts a-c at		p.f., Starting at 25C with no initial load.	
2. Curves are plotted to		Test points so variations should be	
		D.A. Bloomington, Indiana	
		No. 511281	
		Date March 11, 1965	
		<i>George E. Messer</i>	

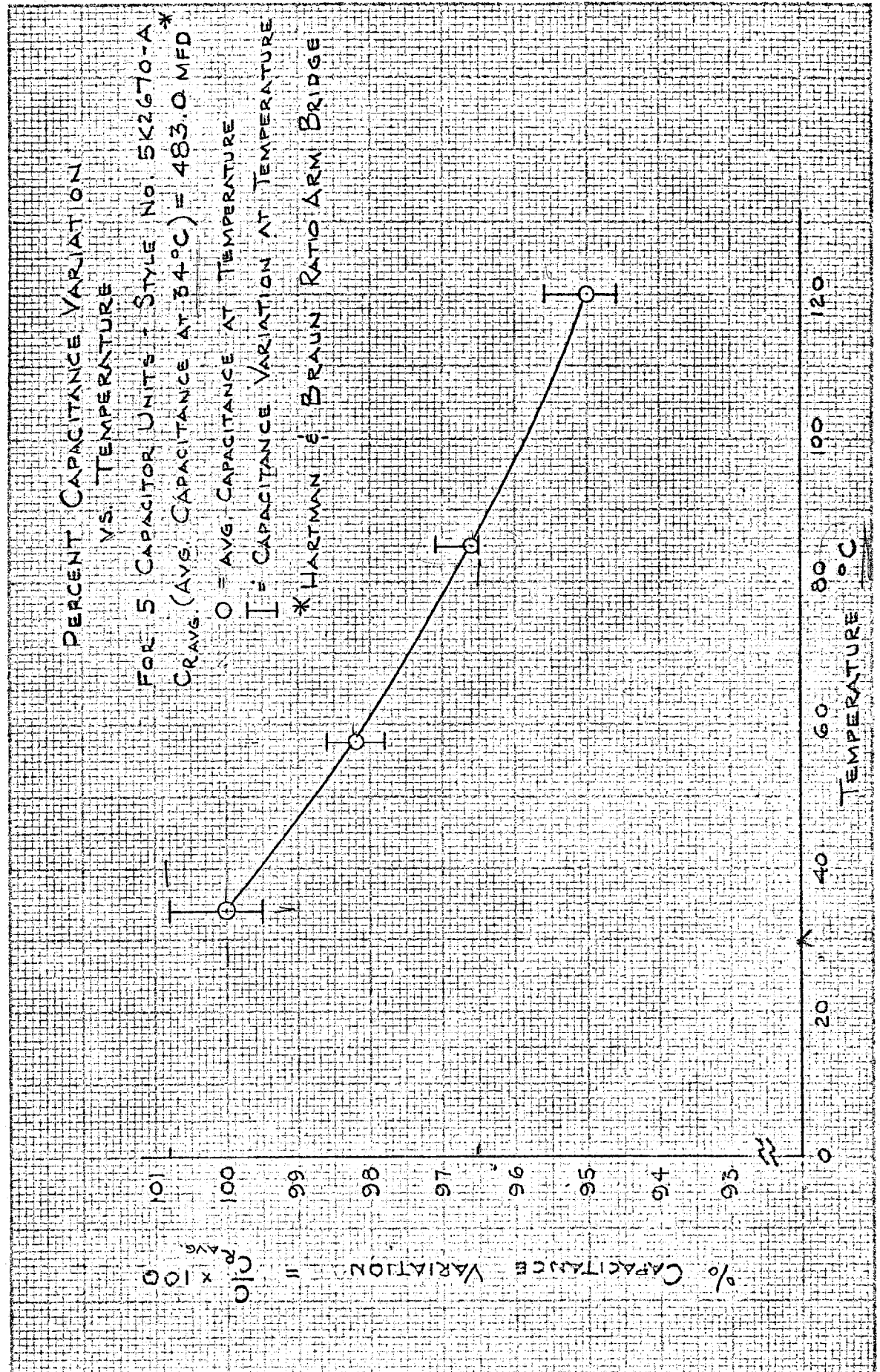


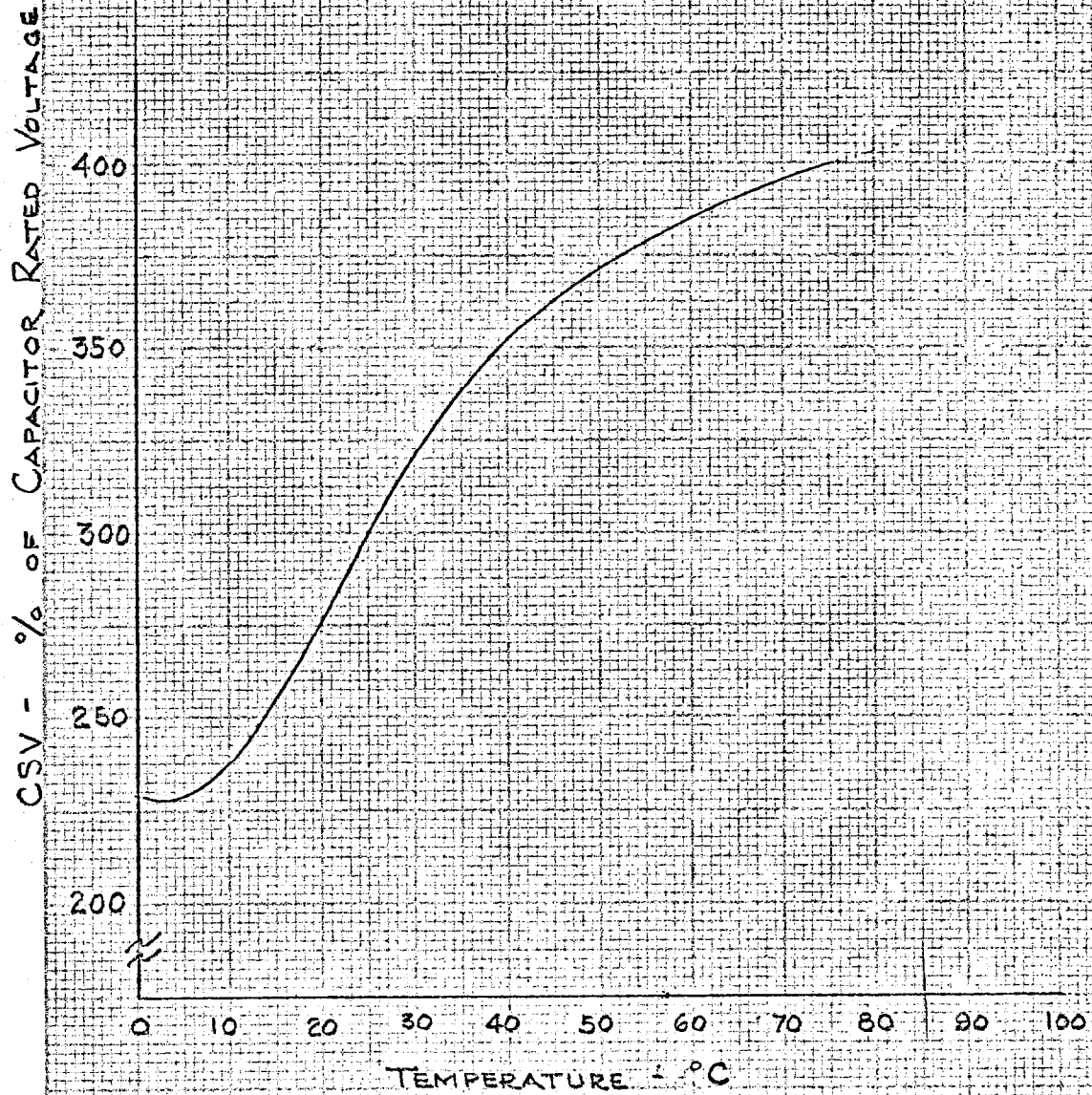
FIG 8.

SIGNATURE *Jim Leigh*

DATE 8/20/69 CURVE NO.

FIG. 9

TYPICAL CHANGE IN CAPACITOR
CORONA STARTING VOLTAGE
AS A FUNCTION OF TEMPERATURE
FOR CAPACITOR UNITS - STYLE No. 5K2670-A



SIGNATURE

Jim Ruff

DATE

8/20/69

CURVE NO.

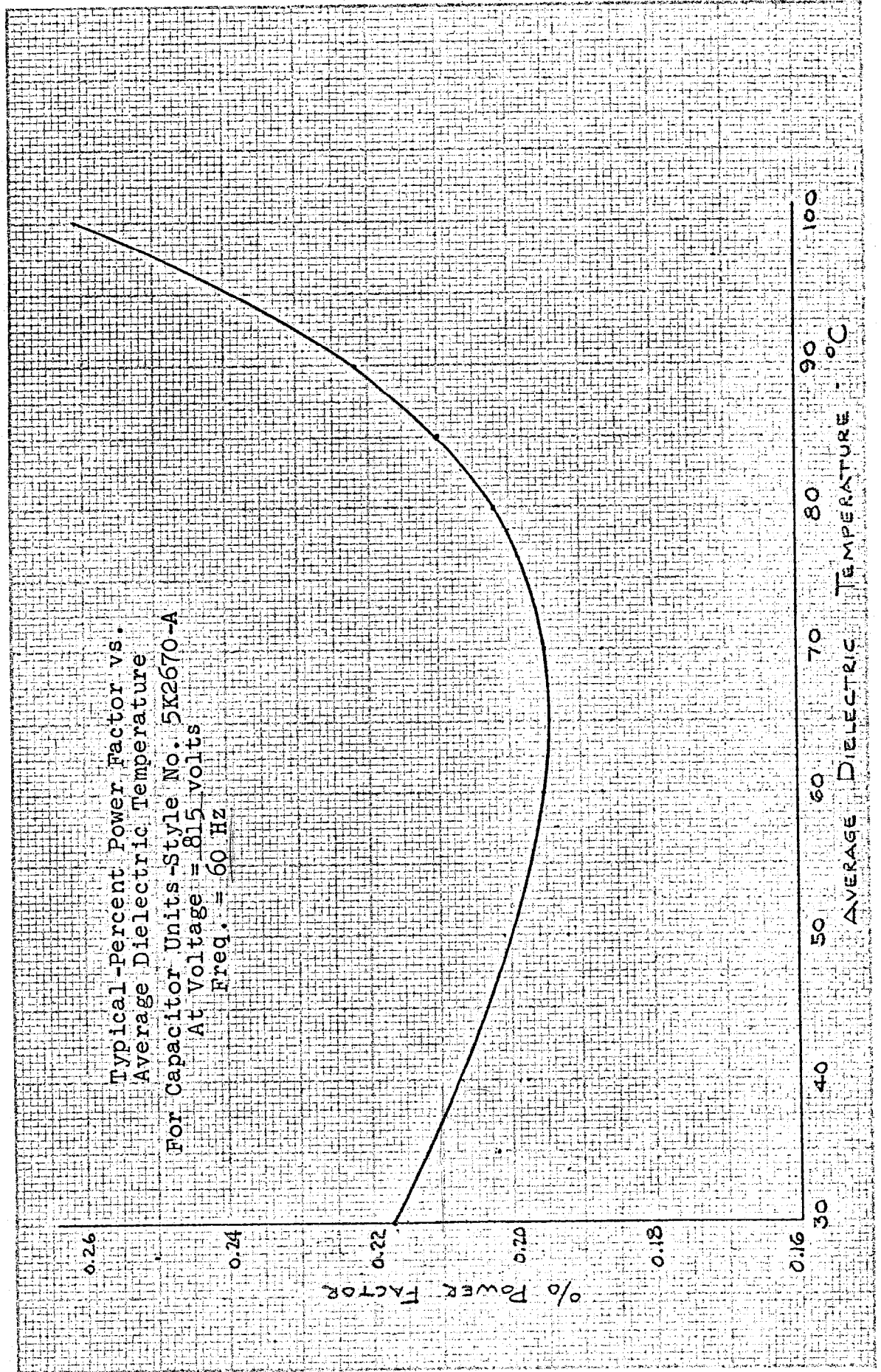


Fig. 10

SIGNATURE Jim Ruff DATE 9/10/69 CURVED NO. TR-2670-C

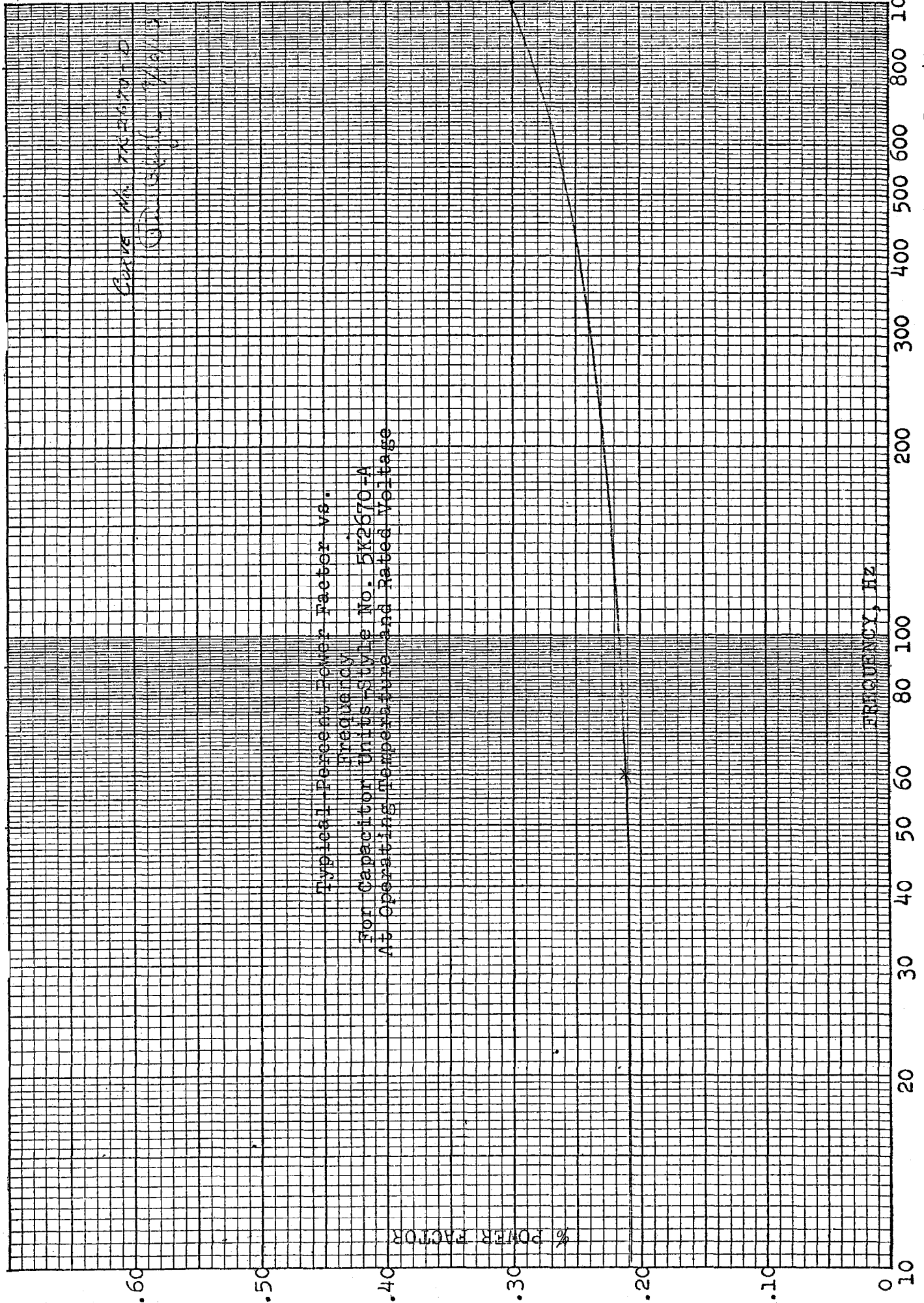


FIG. 11

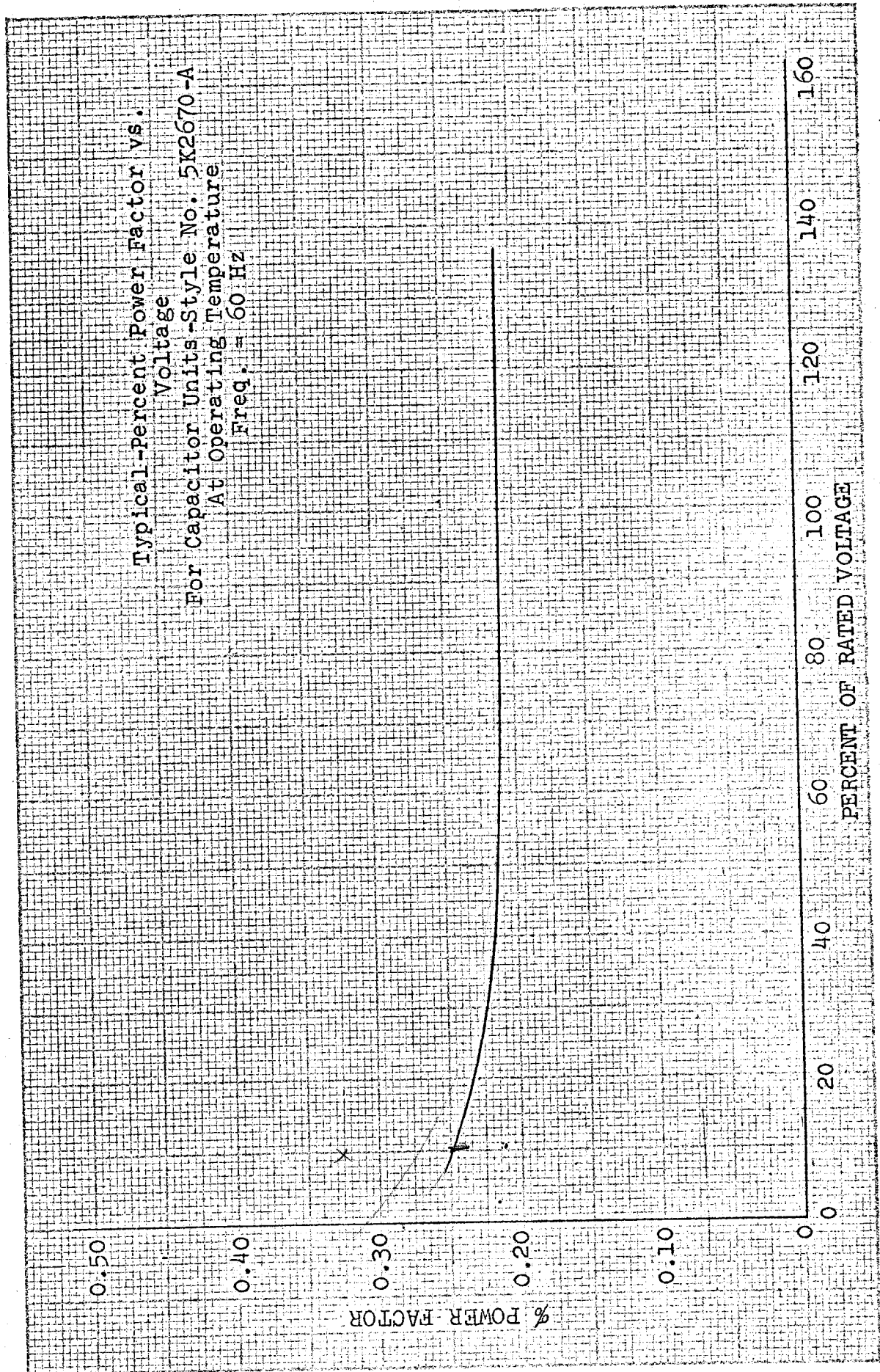


Fig. 12

SIGNATURE Jim Ruff DATE 9/11/69 CURVE NO. TR-2670-E